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Design of Turbocharger in Petrol Engine with Intercooler and Discharger Chamber

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Abstract: Turbochargers are generally in diesel engines & high performance multi cylinder petrol engines to increase the power of the engines by forced induction of atmospheric air into the combustion chamber. The volumetric efficiency of the engines is increased greatly by providing lean air/fuel mixture for combustion into the combustion chamber of the engine. In this work the use of turbochargers in a single cylinder petrol engine is discussed & analyzed. Turbocharger in single cylinder engines is limited due to its torque fluctuations commonly known as Turbo-lag which is not seen in case of multi cylinder engines due its minimized or negligible torque fluctuations. Introduce the discharge chamber or flow control chamber to minimize the effect of turbo-lag, and the concept of intercooler is available in multi cylinder enginesonly. In this Work design mainly caters to the design of a custom intercooler for the use in turbocharged single cylinder engine.
Keyword: Turbochargers, Turbo-lag, single cylinder petrol engine, torque fluctuations, volumetric efficiency.

1. Introduction

The turbocharger was invented in the early 20th century by Alfred Büchi, a Swissengineer and the head of diesel engine research at GebruderSulzer engine manufacturing company. There are two types of forced induction in naturally aspirated engines turbochargers and superchargers. Turbochargers are typically more efficient than superchargers as they work on the exhaust gas power, while a supercharger works on the power derived from the engine crankshaft. Turbocharged engines provide a greater efficiency in terms of power & fuel economy. A 2.0-liter turbo four-cylinder engine can easily match the power of naturally aspirated 3.0-liter V6 engine.

Turbochargers allow an engine to burn more fuel and air by packing more into the existing cylinders. The typical boost provided by a turbocharger is 6 to 8 pounds per square inch. One cause of the inefficiency comes from the fact that the power to spin the turbine is not free. Having a turbine in the exhaust flow increases the restriction in the exhaust. This means that on the exhaust stroke, the engine has to push against a higher back-pressure. This subtracts a little bit of power from the cylinders that are firing at the same time. The turbocharger has been around for decades, and like its cousin, the supercharger, it is a simple way to increase engine power. Both the supercharger and turbocharger are pumps that stuff air into the cylinder, which, when burned with added fuel, creates greater combustion pressure and more power. The supercharger runs off the crankshaft, like the alternator and power-steering pump, and therefore draws some power as it does its job but turbochargers are powered by the normally wasted energy that flows out of the exhaust pipe. One fan lies in the exhaust stream, the other in the intake. The flowing exhaust spins the turbochargers have always been effective at increasing an engine's specific power, otherwise known as the Output per displacement. The Significance of the Turbocharger Better thermal efficiency over both naturally aspirated and supercharged engine when under full load (i.e. on boost). This is because the excess exhaust heat and pressure, which would normally be wasted, contributes some of the work required to compress the air. Weight/Packaging. Smaller and lighter than alternative forced induction systems and may be more easily fitted in an engine bay.

The turbine extracts wasted kinetic and thermal energy from the high-temperature exhaust gas flow and produces the power to drive the compressor, at the cost of a slight increase in pumping losses [2]. The turbocharger improves efficiency of the engine by using the energy contained in the exhaust gasses which are at high pressure and temperature, which helps to drive the compressor. Another ecological advantage is that it features the use of a smaller sized engine and more efficient engine delivering the same level of performance as of the large sized engine [3]. Increase the volume of air entering into the cylinder and the fuel intake proportionately, increasing power and fuel efficiency without hurting the environment or efficiency. This is exactly what Turbochargers do; increasing the volumetric efficiency of an engine in a naturally aspirated engine, the downward stroke of the piston creates an area of low pressure in order to draw more air into the cylinder through the intake valves[4]. The model involves treating the turbocharger as a constant pressure source that is filling the through a connection which has frictional loss. The volume has to be as small as possible to minimize cost, incorporated easily in to the engine, and minimize turbo lag. But it has to be large enough not to experience a significant pressure drop when the engine intakes air.[5,6] The effective size of the turbocharger can be varied based on the amount of exhaust flow, and the turbocharger does not have to be designed for single point performance as done in the past. [6]

2. Turbo Lag and Boost

The time required to bring the turbo up to a speed where it can function effectively is called turbo lag. This is noticed as a hesitation in throttle response when coming off idle. This is symptomatic of the time taken for the exhaust system driving the turbine to come to high pressure and for the turbine rotor to overcome its rotational inertia and reach the speed necessary to supply boost pressure. The directly-driven compressor in a supercharger does not suffer from this problem. Conversely on light loads or at low RPM a turbocharger supplies less boost and the engine acts like a naturally aspirated engine. Turbochargers start producing boost only above a certain exhaust mass flow rate (depending on the size of the turbo). Without an appropriate exhaust gas flow, they logically cannot force air into the engine. The point at full throttle in which the mass flow in the exhaust is strong enough to force air into the engine is known as the boost threshold rpm.

3. Results and Discussion

3.1. Turbocharger for a Single Cylinder Petrol Engine

The main defect of using a turbocharger for a single cylinder Petrol engine is knocking and detonation. Knocking is produced due to the pressure build up inside the cylinder and to reduce this knocking a high octane fuel can be used or the compression ratio must be reduced.

3.2. Discharger chamber

A concept of introducing an expansion chamber between outlet of exhaust and inlet of turbocharger is proposed in order to get a constant flow, as there will be fluctuations in flow of exhaust gas because of only one exhaust stroke for one cycle. The diameter of the chamber will mainly depend up on the diameter of the exhaust pipe. There is also another method in which the length of the exhaust pipe can be increased but this cannot be achieved in a two wheeler, therefore the expansion chamber will be the best suitable method to overcome the problem.

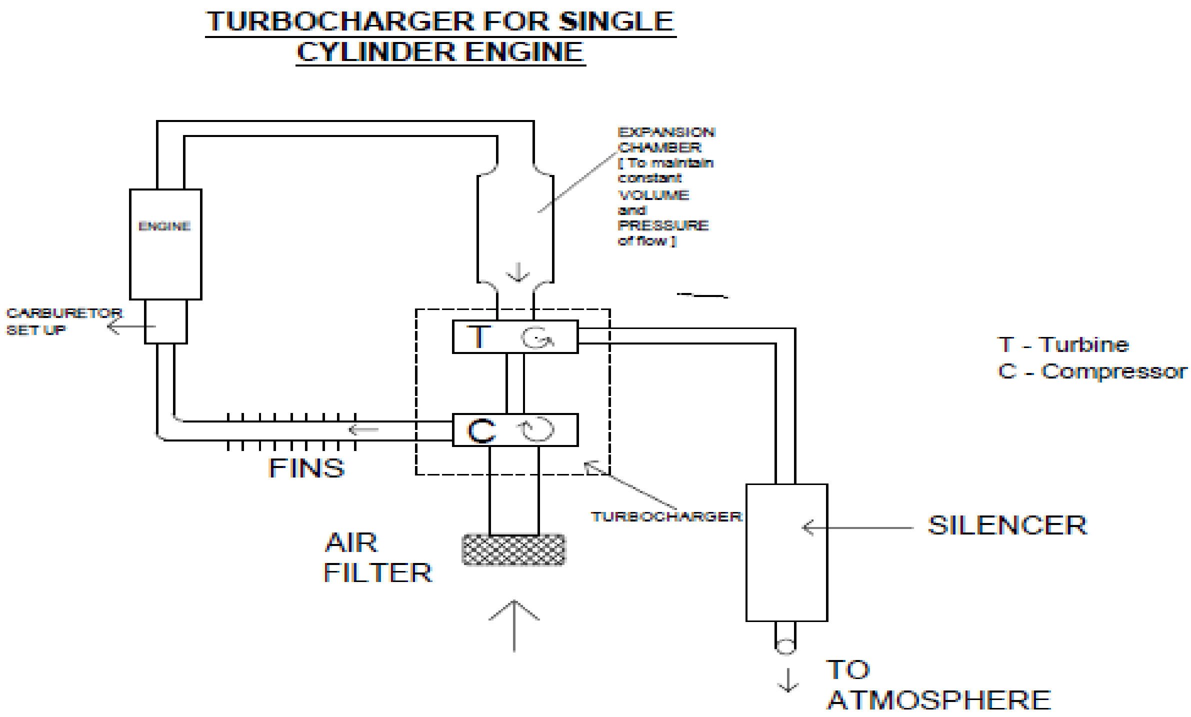

FIG 1: layout of Turbocharger & the discharge chamber

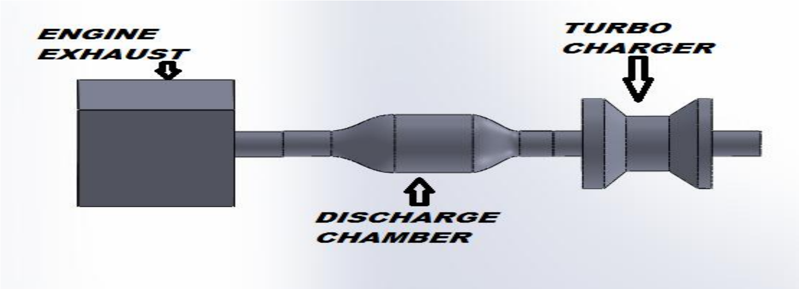

FIG 2: Discharge Chamber

3.3. Engine requirement for Turbocharger

Sl.no	Parameter	Stock	Custom	Reason
1	Compression ratio	9.2:1	Less than 8.5	Using Spacers between head & cylinder or using low compression pistons
2	Fuel system	Carburetor	Fuel injection	Withstand the boost pressure
3	Air/Fuel ratio	16.1	12.1:1	Preventing knocking/detonation
4	Intercooler	-	Air to air/fluid	Increasing charge density
5	ECU	-	CDI controlled	For ignition timing & fuel injection Onboard diagnosis

Table 1: Engine Requirements

3.4. Compressor Chart or Garrett Chart

The first and foremost thing is to select the correct dimensions and parameters for a compressorso compressor chart is utilize to select the blade dimension to the requirement.

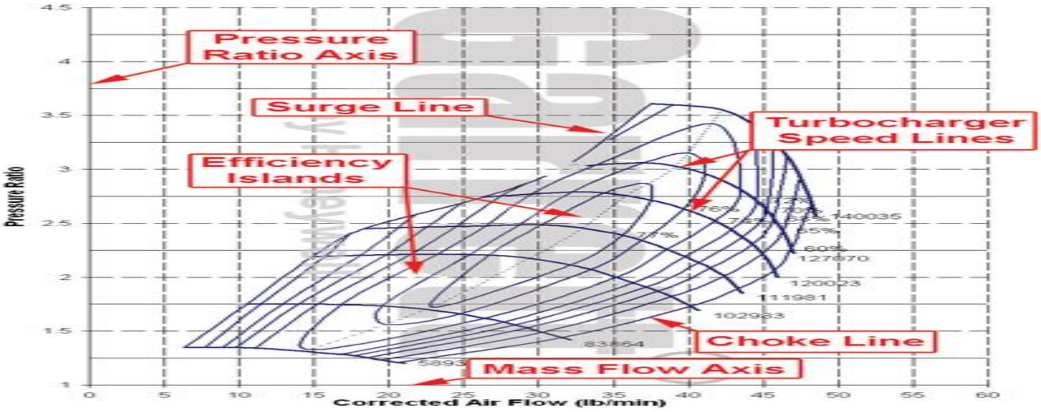

Fig 3: Compressor and Garrett Chart

4. Design Data

Input Variables		
Target Flywheel Horsepower	20	HP
Target AIR/FUEL Mixture	12:1	
Displacement	0.125	lit
Number Of Cylinders	1	
Peak Volumetric Efficiency	75	%
Brake Specific Fuel Consumption (BSFC)	0.55	lb/(hp*hr)
Redline	7500	rpm
Peak Torque	5500	rpm
Pressure loss before Compressor	1	psi
Compressor Map Requirements		
Required airflow	1.61 to 2.20	lb/min
	16.31 to 20.06	CFM
	at	
	5500 to 7500	rpm
Boost Requirements		
Required Absolute Manifold Pressure	37.26	psi
Required Gauge Manifold Pressure	22.54	psi
Engine Requirements		
Charge Air temperature at Manifold	183.7	F
Required injector Size	138.6	cc/min
Brake Mean effective Pressure	277	psi

Table 2: Intercooler Efficiency
The table show the input dimensions, requirement for the engine, compressor

The Intercooler Efficiency is found by the temperature drop of the exhaust gas by the intercooler to the temperature rise by the compressor, this is similar to the Intercooler Gain, but this number is more applicable to the exact intercooler without influences from the turbo/engine/piping/etc.

4.1. Compressor dimensions

Axial width of the impeller in meridional view (mm) = 39.257
Inner diameter at compressor inlet (mm) = 12
Outlet diameter at compressor inlet (mm) = 36.25
Impeller outer diameter (mm) = 49
Impeller width at trailing edge (mm) = 5
Diffuser exit diameter (mm) = 55
Throat length at leading edge (mm) = 9.760
Total number of blades
Main blades = 6
Splitter blades = 6
Inducer Wheel diameter (mm) = 22.63
Exducer Wheel Diameter (mm) = 32
Trim = 50
Aspect/Ratio = 0.32

5. Experimental Setup

Fig 4: Experimental Setup

6. Design of Compressor Impeller

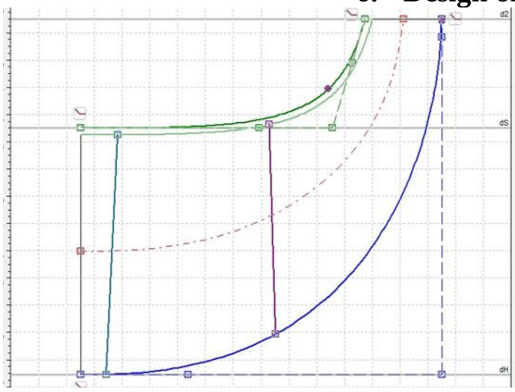

Fig 5: Meriodinal view of Impeller Blade

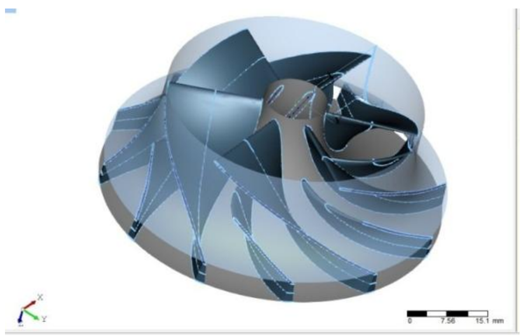

Fig 6: Impeller blade

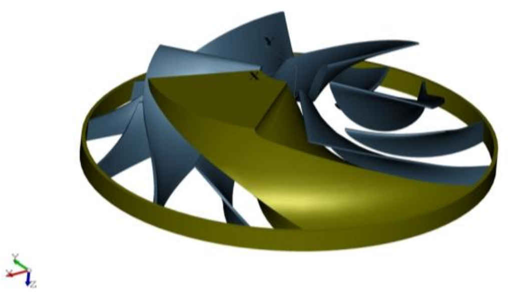

Fig 7: Flow domain through the impeller blade

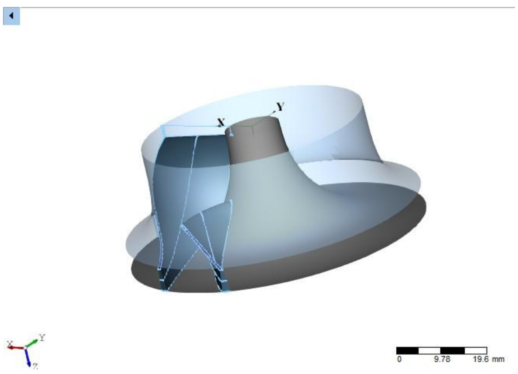

Fig 8: Splitter blade view

When air is compressed, it heats up and expands. In order to increase the power of the engine,more quantity of air fuel has to be inducted into the engine. For every 10^{o} C drop in inlet air temperature, the power produced increases by 1% and high temperature air inlet is a main cause for Knocking. From the reference of various studies, when the temperature of inlet air reduces, the engines performance increases .To reduce the air temperature an intercooler is used. An intercooler is an additional component that looks something like a radiator, except air passes through the inside as well as the outside of the intercooler. The intercooler acts as a heat exchanger which dissipates heat from the compressed air to the atmosphere thereby reducing its temperature.

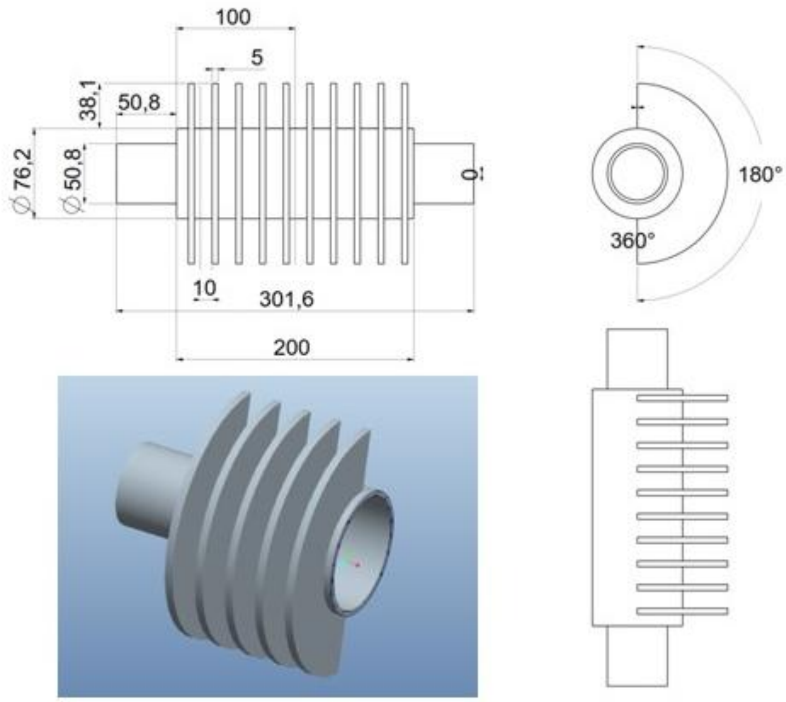

Fig 9: View of the Intercooler

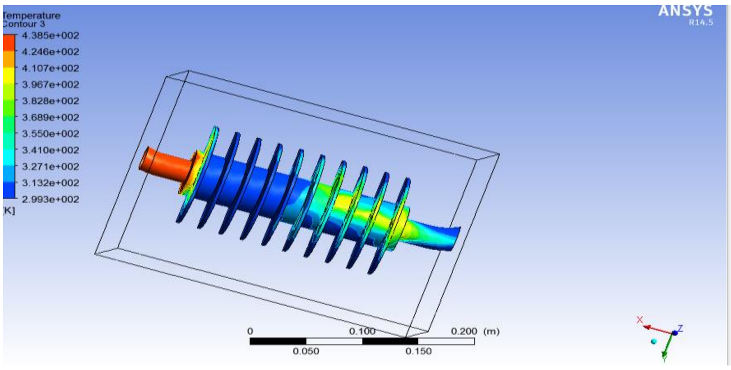

Fig 10: Flow analysis of Intercooler

7. Conclusion

The concept of turbo charging for a 125cc engine powered by gasoline, accompanied by the design of the most critical segment of the turbocharger that is the compressor & intercooler is done with the help of suitable 3D design software considering all the important parameters that limit the design criteria. This challenging design process and implementation of the turbo charging for a lower CC engine was efficiently done and the design results are tested for accuracy.

The usage of the turbocharger for a gasoline engine will enhance the performance of the vehicle in terms of power as the boost pressure that is obtained is very high which in turn increases the performance. The concept of turbo charging is in the developmental stage for a petrol engine of lower cc and this will succeed in the implementation of that concept with high efficiency.

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